Research on Optical Input and Output Structures for the SOI Slab Optical Waveguide

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修士学位論文要約（令和２年３月）

SOI スラブ光導波路への光入出力構造に関する研究

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Research on Optical Input and Output Structures for the SOI Slab Optical Waveguide

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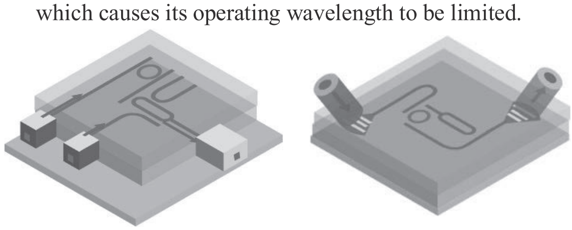
The optical input and output structure of the optical integrated circuit using silicon photonics technology is a way for the integrated circuit to communicate with the external components. However, the traditional optical input and output methods have problems such as restricted installation places and narrow wavelength band, which makes the performance of the optical input and output structure not high. Since a directional coupler can cause light to propagate in two waveguides without contact, it has the possibility of improving the degree of freedom of the optical input and output structure. Therefore, in this study, in order to improve the degree of freedom and widen the wavelength band, an upper layer coupling method based on a channel waveguide and an elliptical mirror reflection was proposed. After a series of design and improvement, its effectiveness was actually proved.

1. Introduction

In recent years, the silicon optical technology has developed rapidly [1]. The optical input and output structure as a component of the optical integrated circuit is a way for the information exchange between the waveguide circuit and external components. There are two existing optical input and output structures shown in Fig.1.1, one is an edge face structure and the other is a grating coupler structure. The edge face structure is a structure in which an external waveguide and an integrated waveguide are directly connected. It can achieve high transmission efficiency over a wide range of wavelength, but it can only be set on smooth edge faces that are difficult to manufacture in practice. The structure of the grating coupler can use the grating to input and output light. It overcomes the disadvantage that it can only be set on the edge face, and can be set at any position of the optical integrated circuit, which greatly increases the freedom of component layout. However, its transmittable wavelength range is relatively narrow, which causes its operating wavelength to be limited.



(a) edge face structure　　(b)grating coupler structure

Fig.1.1 existing optical input and output structures

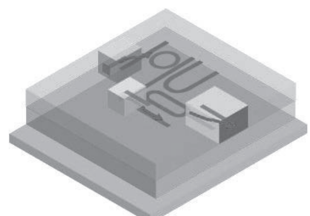


Fig.1.2 upper layer coupling structure

If the two input and output methods can be combined as shown in Fig.1.2, it is possible to overcome their disadvantages and obtain advantages.

2. Evaluation of the Optical Input Method of the Upper Layer Coupling Structure

There are two types of optical waveguides, one is a channel waveguide, and the other is a slab waveguide. When applying a directional coupler composed of channel waveguides to this study, it is necessary to consider the situation where two parallel waveguides are shifted like Fig.2.1. After simulation calculations, when two 2 μm× 0.2 μm waveguides are shifted by 0.4 μm, their transmission efficiency is attenuated to 50%, and the attenuation speed is very fast. Therefore, a structure in which a slab waveguide shown in Fig.2.2 are used for coupling is proposed here. This is because the slab waveguide is very wide, and even if the channel waveguide is shifted, the coupling efficiency will not be attenuated. Therefore, the design and simulation of the coupling structure between the channel waveguide and the slab waveguide were carried out.

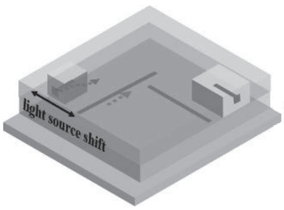


Fig.2.1 a problem of upper layer coupling structure

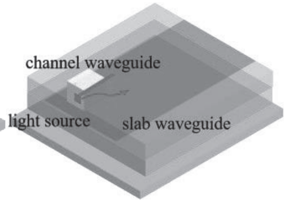


Fig.2.2 upper layer coupling structure with slab waveguide

After specific simulation, the corresponding transmission efficiency is 98% at a wavelength of 1.55 μm, and the transmission efficiency is over 91% at a wavelength range of 1.44 μm to 1.65 μm. It can be confirmed that this structure has good transmission efficiency and wavelength dependence.

Here the elliptical mirror is used to collect light. The reflection of the light beam can be easily controlled according to the focal light receiving characteristics of the elliptical mirror. According to the propagation theory of Gaussian light and the ABCD rule of prisms, the reflection of Gaussian light on an elliptical mirror is calculated. According to the obtained formula, the most suitable light source placement position is calculated. It is worth noting that due to the existence of the evanescent wave phenomenon, the actual reflection surface is not an ideal elliptical surface, so even under the most suitable conditions, its maximum reflection efficiency is only about 94%.

3. Evaluation of the Light Output Method of the Upper Layer Coupling Structure

First, in order to understand the transmission of the light beam collected by the elliptical mirror directly connected to the waveguide, a channel waveguide is set at the output position. In order to observe the attenuation of the light beam in the channel waveguide, two electromagnetic field monitors were set on the output channel waveguide, and they were separated by 20 μm. After simulation, the value of monitor m1 is 90.6%, and the value of monitor m2 is 90.58%. It can be seen that while obtaining high transmission efficiency, its attenuation is very small.

Then, due to the symmetry of the optical path, it can be considered that the light beam can be coupled into the upper channel waveguide without contact. So, a channel waveguide was placed on top of the slab waveguide, and the simulation was performed. The value of monitor m1 is 91.4%, and the value of monitor m2 is 91.39%. It can be considered that compared with contact, non-contact method will increase transmission efficiency while attenuation is still small.

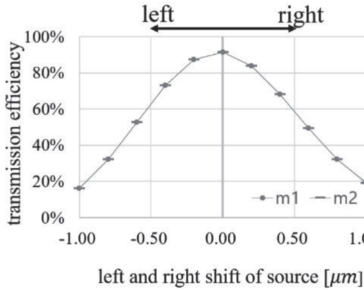


Fig.3.1 the relation of transmission efficiency and left and right shift of source

Since the deviations of the light source and the output channel waveguides in the front-back, left-right, and angle will occur in the actual production process, it is necessary to explore the influence of these deviations on the overall structure. Here the front, back and left are the directions facing the mirror. First, explore the effect of light source position deviation.

Among them, the deviation of the light source in the left and right directions is first explored. After simulation, as shown in Fig.3.1, when the deviation in the left and right directions is ± 0.6 μm, the transmission efficiency is greater than 50%. And due to the existence of the evanescent wave phenomenon, the position corresponding to the highest transmission efficiency is shifted to the left by 0.03 μm. It can be seen from this that the left and right offset of the light source has a very large impact on the transmission efficiency.

4.Conclusion

This research proposes an upper input and output structure that is different from the conventional end-face and grating structures, and confirms its effectiveness. According to the simulation results, the upper layer input-output structure in this study can achieve high degrees of freedom while achieving high efficiency in the broadband domain. Finally, the influence of various possible deviations on the overall structure is analyzed.

Reference

1) Sakai Atsushi, Fukazawa Tatsuhiko, Baba Toshihiko. Estimation of Polarization Crosstalk at a Micro-Bend in Si-Photonic Wire Waveguide [J]. Lightwave Technology, **22**(2004), 502.